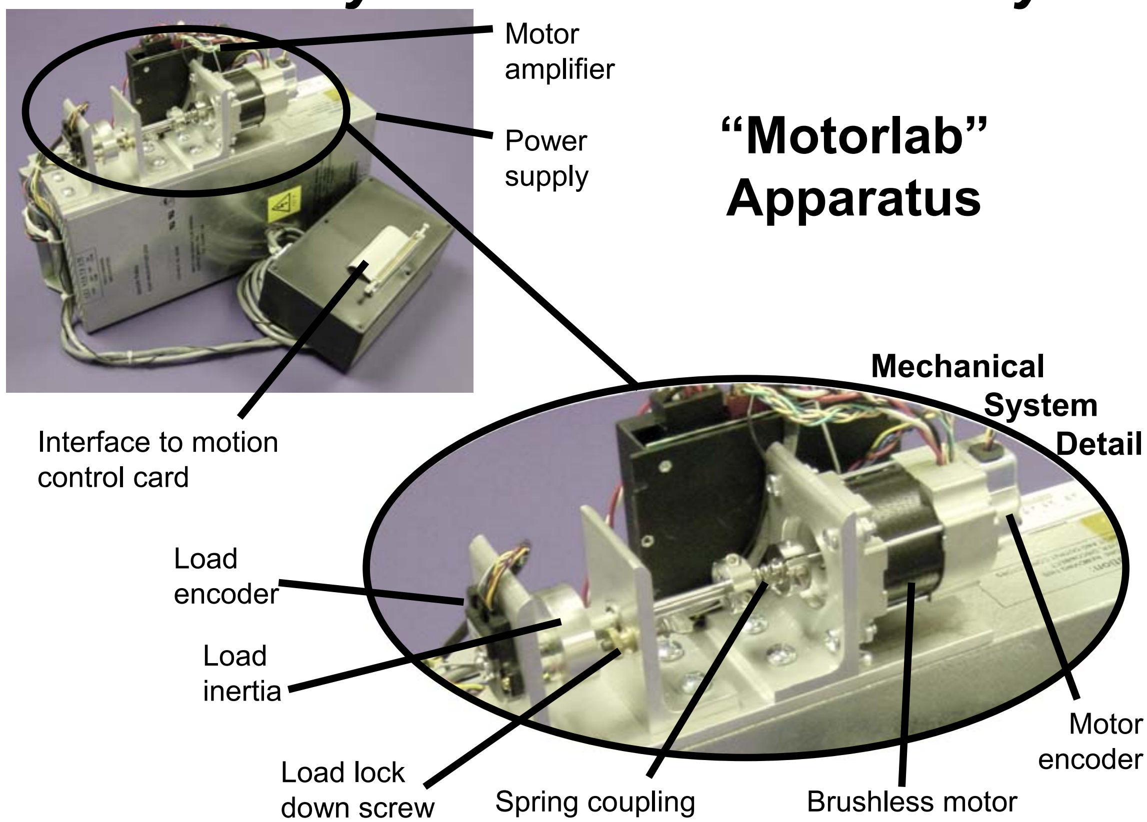
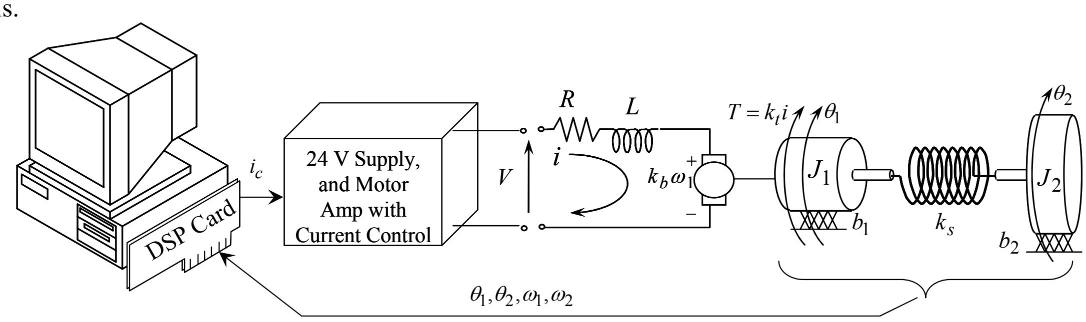
“Motorlab” Dynamics and Controls System

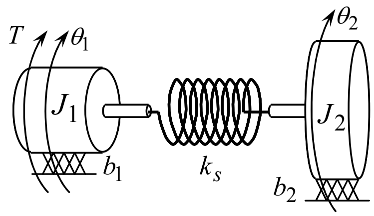


System Description

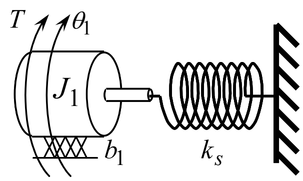
Below is a schematic representation of the motorlab system in a closed-loop position or velocity control configuration. There are two position sensors on the apparatus. The position of the motor inertia is measured using the motor encoder and the position of the load inertia is measured using the load encoder. This is done using hardware on the DSP motion control card that counts the pulses from the encoders. Each pulse corresponds to a certain increment of rotation. The velocities of the two inertias are measured using hardware on the MC4000 motion control card that measures the time between pulses coming from the encoders. The motor amplifier has a control loop that measures and controls the electric current in the motor windings. This results in what is commonly known as a “torque controlled” motor, since the magnetic torque is proportional to the current in the windings. The DSP motion control card is interfaced to the motor amplifier through a +/-10V analog signal from a digital to analog converter (DAC) on the card. By varying the magnitude of this voltage from the DAC the current in the motor is varied. This voltage, which is proportional to the controlled current, serves as a current command for the current control loop in the amplifier. An additional sensor, not shown below, is the current sensor in the amplifier. This sensor is also read by the DSP card, using an analog to digital converter (ADC) to read the actual current measured by the amplifier. Although this signal is not used in the control loops on the DSP card, it is recorded for data analysis.



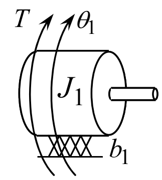
Several different configurations of the system can be utilized in experiments. Either sensor, the motor or load encoder, can be used for the feedback of the control loop. The selection is made in the software interface. The motor encoder is known as a "collocated" sensor since it is co-located with the input to the mechanical system, the motor torque. The load sensor is separated from the input to the system by a spring and is therefore known as a "non-collocated" sensor. In addition to varying which sensor is used, the mechanical system can be changed with the lock down screw and the spring coupling. Also, a choice can be made between velocity control or position control by selecting the appropriate control program. Any of the following mechanical models may be realized using the motorlab hardware and software.



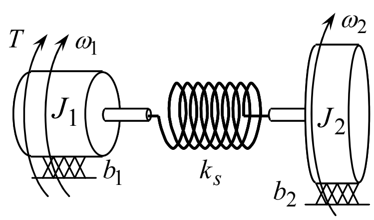
Fourth order system with a free integrator



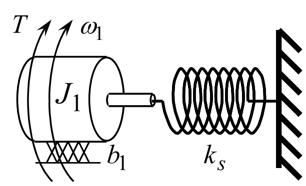
Second order system



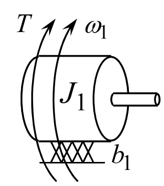
Second order system with a free integrator



Third order system



Second order system with a free differentiator



First order system

Software

The software can be found in the "c:\motorlab" directory on the laboratory machines. All the needed functions and shortcuts to the executables can be found here. The "c:\motorlab\student data" directory can be used to store data files and gain files temporarily. It should be cleaned out at the end of the lab session. Students have read/write/delete access to this directory.

Control Software

There are three different programs used to control the motorlab hardware. Each program consists of a GUI interface that runs on the host PC and a low-level control program that runs on the DSP microprocessor on the MC4000 motion control card. The PC's processor and the DSP communicate over the PCI bus in the host computer. For the two programs that implement closed loop control, a PID controller is used. In addition the user has the option of including feedforward velocity and acceleration gains. Each of the three programs may be run by executing the host program, which loads the appropriate DSP program onto the motion control card and begins its execution. ***WARNING: The software will not function properly if more than one host program is running.*** The three programs are described below.

MotorLabOL.exe

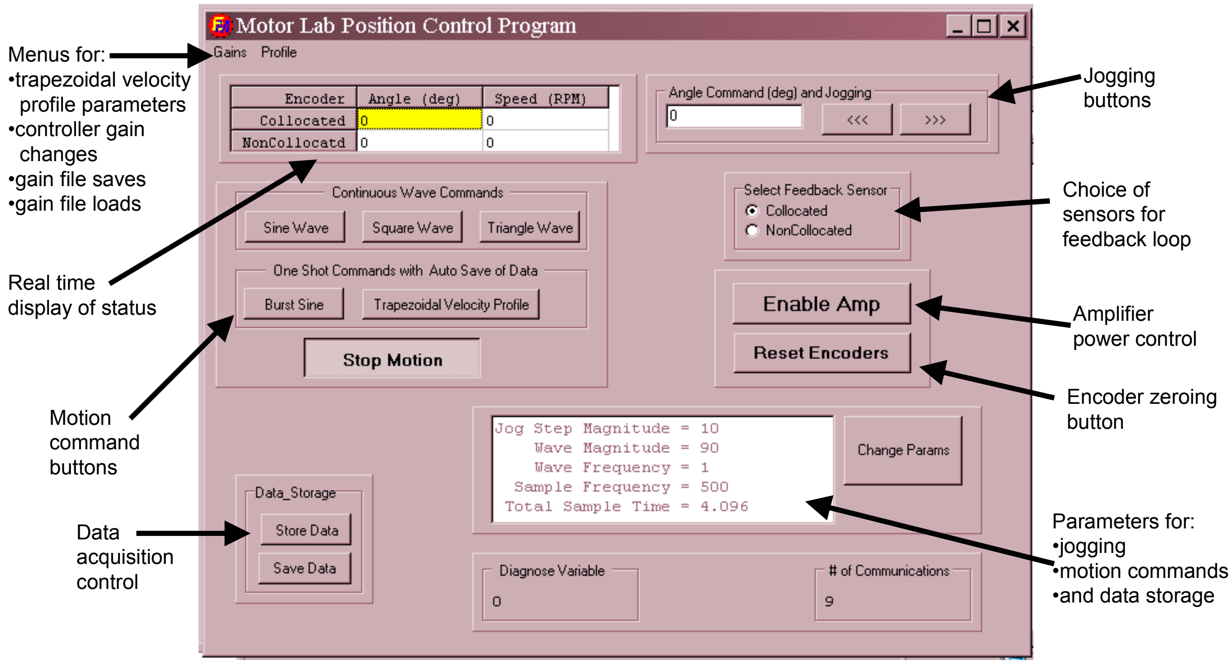
This is the open loop program. The feedback sensors (encoders) are not actually used for closed loop control. The DAC output from the motion control card to the motor amplifier is determined directly by the wave command buttons and the jog buttons.

MotorLabPosition.exe

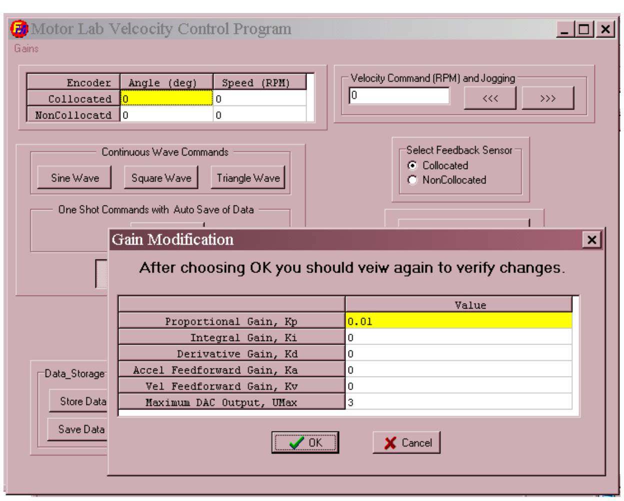
This is the position control program. The feedback sensors (encoders) are used to close the position control loop. The DAC output from the motion control card to the motor amplifier is determined by the controller algorithm, while the position command is determined by the wave command buttons and the jog buttons.

MotorLabVelocity.exe

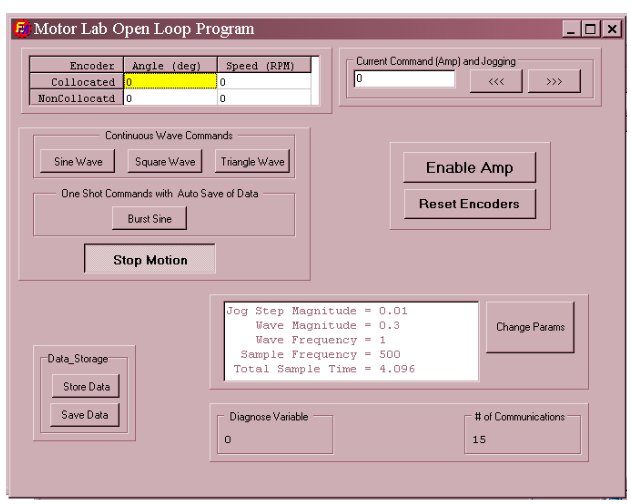
This is the velocity control program. The feedback sensors (encoders) are used to close the velocity control loop. The DAC output from the motion control card to the motor amplifier is determined by the controller algorithm, while the velocity command is determined by the wave command buttons and the jog buttons.



Position Control Host-Computer Interface



Velocity Control Host-Computer Interface Showing Gain-Change Dialog



Open Loop Host-Computer Interface

Data Acquisition

When the “Store Data” button is pressed in the host GUI the software stores data from the dynamic system in a circular buffer. The buffer is 2048 data samples in length. After 2048 sample periods the buffer begins to be overwritten, and will continue to be overwritten as long as the “Store Data” button is depressed in the host program. Pressing either the “Save Data” button or the “Store Data” button again will stop data storage, leaving the last 2048 data samples in the buffer. If for example the sample rate is set to 500 Hz, then the last 2048/500=4.096 seconds of data will be saved in the buffer. The data is saved to a file by pressing the “Save Data” button.

The exception to the sampling scheme above occurs when one of the command buttons in the “One Shot Commands with Auto Save of Data” is pressed. In this case the command generation and the data storage execute until the buffer fills. Then the data is automatically stored to a data file named with the time and date from the computer clock.

Nine pieces of data are stored at each time step (each sample period):
TIME(sec) Command(deg/RPM/Amps) Theta1(deg) Theta2(deg) Vel1(RPM) Vel2(RPM) U(Amps) I(Amp) Extra(??)
The *TIME* data begins at zero with the oldest data point in the buffer. The units of the *Command* depend upon which program is running: closed-loop position control, closed-loop velocity control, or the open loop program. The *U* variable is the commanded current to the amplifier, and the *I* variable is the measured current. The *Extra* variable is reserved for future use.

Associated MATLAB functions for data analysis

File: mlimport.m function data = mlimport(); Opens a dialogue to select a data file generated by the motor lab software. Returns the data in the selected file through a matrix with 9 columns and 2048 rows. The 9 columns of the matrix contain the following data:
TIME(sec) Command(deg/RPM/Amps) Theta1(deg) Theta2(deg) Vel1(RPM) Vel2(RPM) U(Amps) I(Amp) Extra(??)
example: data = mlimport;

File: mlolplots.m function mlolplots(data,Iscale); Uses data generated by the motorlab openloop control software and imported using mlimport.m. Plots the motion variables along with the current command to the amplifier. If an "Iscale" argument is supplied then the commanded current values are scaled by the Iscale value in the plots.
example: mlolplots(data); Does not scale the current command.
example: mlolplots(data,Iscale); Multiplies commanded current values by Iscale.

File: mlposplots.m function mlposplots(data); Uses data generated by the motorlab position control software that has been imported using mlimport(). Plots this data in several plots. example: mlposplots(data);

File: mlvelplots.m function mlvelplots(data); Uses data generated by the motorlab velocity control software that has been imported using mlimport(). Plots this data in several plots. example: mlvelplots(data);

File: trapprof.m function [x,v,t] =trapprof(DX,Vmax,Amax,DT) Trapezoidal-velocity motion profile generation
Outputs: x=position vector, v=trapezoidal velocity vector, t=time vector
Inputs: DX=distance to move, Vmax=maximum velocity, Amax=maximum acceleration, DT=time step for outputs
example: [x,v,t] =trapprof(DX,Vmax,Amax,DT)

Associated EXCEL programs

Three EXCEL files/programs are also included in the motorlab directory: “Open Loop Plots.xls,” “Position Control Plots.xls,” and “Velocity Control Plots.xls.” Each of these files contains a Visual Basic GUI interface in the “HeaderSheet” sheet of the file. The GUI’s are used to import data files for the plot sheets. These files essentially implement the same plots as the three plot functions for MATLAB discussed above.

Hardware Specifications

Important Scaling Considerations

- Motor Amplifier Scaling = 1 Amp/Volt (i.e. one volt from the DAC on the MC4000 is a one Amp command to the current loop in the motor amplifier). The plotting routines provided take this scaling into consideration.
- Position is measured in degrees and velocity is measured in RPM. The output of the controller algorithm on the MC4000 is the DAC voltage, and is measured in Volts. Therefore, for example, the units of the proportional and derivate gains in the position controller would be Volts/deg and Volts*sec/deg, respectively. When multiplied by the amplifier scaling (1 Amp/Volt) these gains become Amps/deg and Amps*sec/deg. The units of the proportional gain in the velocity controller would be Volts/RPM (or Amps/RPM if amplifier scaling is included).

Inertias

Object	Motor Rotor and Motor Encoder	Stainless Steel Coupling Collar	Stainless Steel Load Shaft	Aluminum Spacer for Load	Aluminum Load Inertia	Load Encoder
Approx. Inertia (g-cm^2)	110	13.04	1.423	0.079	81.91	0.83

A Few Other Details

- Max motor velocity with the amplifier used is about 4000 rpm
- Max Data Acquisition Sample Rate = 10 kHz (the servo update rate of the DSP software)
- Motor Encoder Resolution = 360/1600 = 0.225 deg/count
- Load Encoder Resolution =360/2000=0.180 deg/count

Velocity measurement

The velocity is measured on the DSP motion control card using a timer to measure the time between encoder pulses ($\omega \cong \Delta\theta / \Delta t$). This results in a time delay in the velocity measurement that can become very significant at low velocity. This time delay can have a significant affect on a velocity controller and on the derivative term in a PID position controller. If for example the motor encoder is spinning at 20 rpm then the time delay would be

$$\Delta t = \Delta\theta / \omega = \frac{0.225\,\text{deg}}{20\,\text{rev/min}} \cdot \frac{\text{rev}}{360\,\text{deg}} \cdot \frac{60\,\text{sec}}{\text{min}} = 0.002\,\text{sec}$$

Theoretically, it is not possible to measure zero velocity.

Specs from Motor Manufacturer's Data Sheet

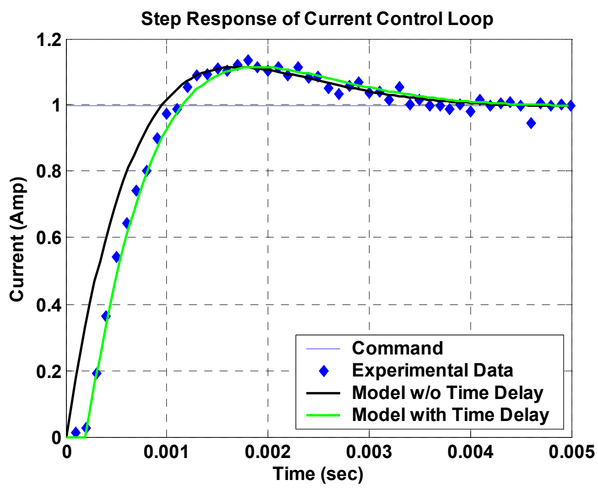
LA052-040E Motor Dynamic Specs From Shinano Kenshi		
	UNITS	Value
RATED POWER	W	40
RATED VOLTAGE	VDC	24
RATED SPEED	rpm	3,000
RATED TORQUE	N-cm	12.7
	kgf-cm	1.3
RATED CURRENT	A	2.5
TORQUE CONSTANT	N-cm/A	5.0
	kgf-cm/A	0.51
BACK EMF CONSTANT	V/krpm	5.2
PHASE RESISTANCE	Ohm	1.18
PHASE INDUCTANCE	mH	4.4
INSTANTANEOUS PEAK TORQUE	N-cm	38.2
MAX SPEED	rpm	5,000
ROTOR INERTIA	g-cm^2	110
POWER RATE	kW/s	1.48
MECHANICAL TIME CONSTANT	ms	5.2
ELECTRICAL TIME CONSTANT	ms	3.7
MASS	kg	0.6

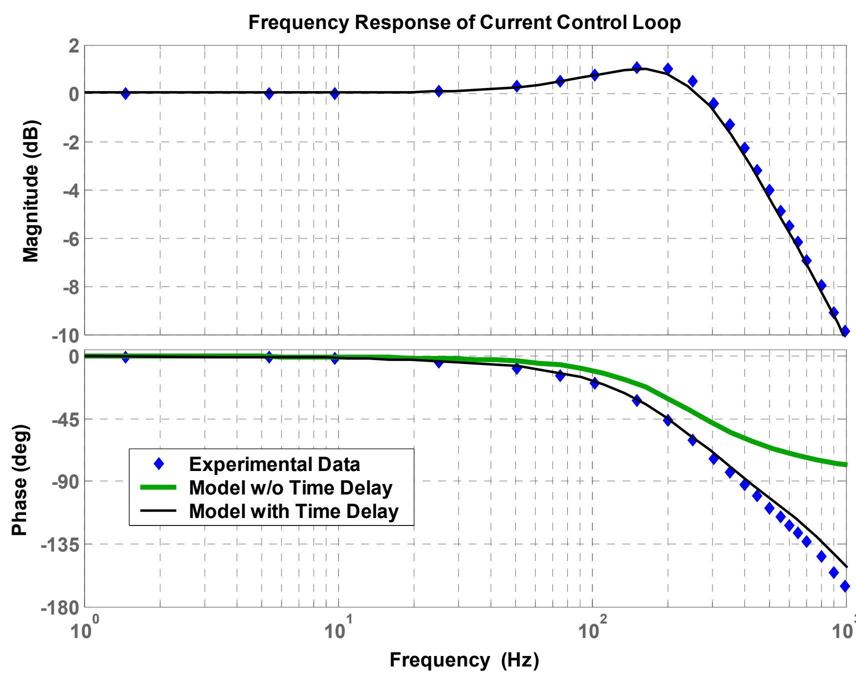
Current Control Loop Model

The motor amplifier has a current control loop. As configured in the Motorlab apparatus this loop has a bandwidth of approximately 400 Hz. Using data acquired from step and sinusoidal responses the following two closed loop transfer functions have been identified as approximate models for the closed-loop current control dynamics.

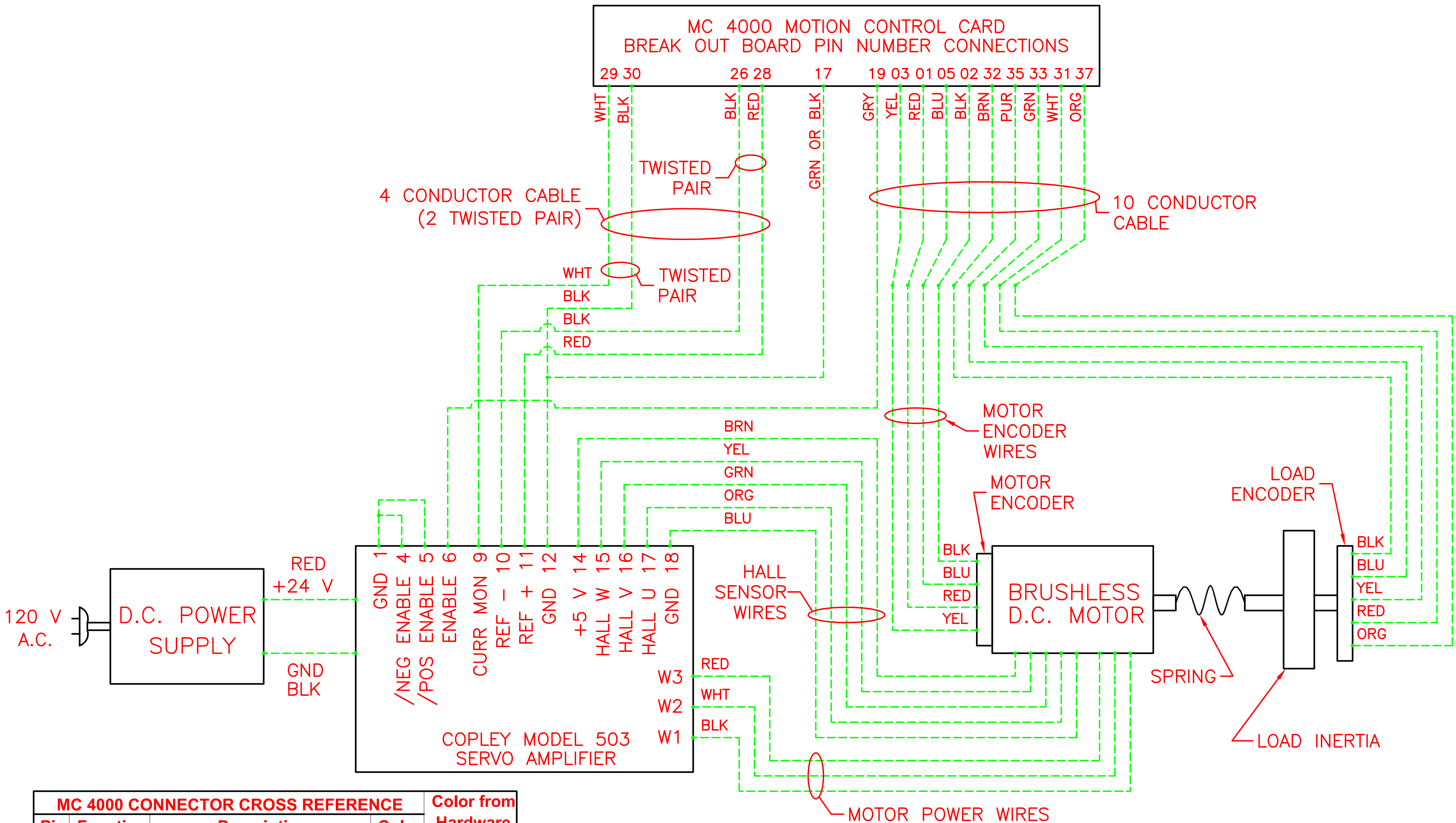
$$T_i = \frac{\omega_n{}^2 (s+z)}{z(s^2 + 2\varsigma\omega_n s + \omega_n{}^2)} \quad \text{and} \quad T_{idelay} = \frac{\omega_n{}^2 (s+z)}{z(s^2 + 2\varsigma\omega_n s + \omega_n{}^2)} e^{-t_d s} \quad \text{where} \quad \begin{aligned} z &= 170 \cdot 2\pi \ \ \textit{(rad/sec)} \\ \omega_n &= 230 \cdot 2\pi \ \ \textit{(rad/sec)} \\ \varsigma &= 0.8 \\ t_d &= 0.0002 \ \ \textit{(sec)} \end{aligned}$$

One of the models above contains a time delay while the other does not. In the following two figures the responses of these two models are compared with actual data acquired from one of the Motorlab systems. Both the step response and the frequency response models are shown.





Schematic For the “Motorlab” Apparatus



MOTOR TEST STAND WIRING SCHEMATIC

MC 4000 CONNECTOR CROSS REFERENCE				Color from Hardware
Pin	Function	Description	Color	
1	+5V	+5V Power for Encoders	Red	Red
2	GND	Encoder Ground	Black	Black
3	A0	Encoder Channel A0	Yellow	Yellow
5	B0	Encoder Channel B0	Blue	Blue
17	GND	Digital Ground	Green/ Black	
19	DOUT0-0	Amp Enable1-0	Gray	
26	AGND	Analog Ground	Black	
28	DAC0	Analog Output0	Red	
29	AD+0	Analog Input +ve Differential Line-0	White	
30	AD-0	Analog Input -ve Differential Line-0	Black	
31	+5V	+5V Power for Encoders	White	Red
32	GND	Encoder Ground	Brown	Black
33	A1	Encoder Channel A1	Green	Yellow
35	B1	Encoder Channel B1	Purple	Blue
37	Z1	Encoder Channel Index Pulse1	Orange	Orange

Manual for the Motor Amplifier

Model 503
DC Brushless Servo Amplifier

FEATURES

- ***CE Compliance to 89/336/EEC***
- ***Recognized Component to UL 508C***
- **Complete torque (current) mode functional block**
- **Drives motor with 60° or 120° Halls**
- **Single supply voltage 18-55VDC**
- **5A continuous, 10A peak more than double the power output of servo chip sets**
- **Fault protected**
  Short-circuits from output to output, output to ground
  Over/under voltage
  Over temperature
  Self-reset or latch-off
- **2.5kHz bandwidth**
- **Wide load inductance range 0.2 to 40 mH.**
- **+5, +15V Hall power**
- **Separate continuous, peak, and peak-time current limits**
- **Surface mount technology**

APPLICATIONS

- **X-Y stages**
- **Robotics**
- **Automated assembly machinery**
- **Component insertion machines**

THE *OEM* ADVANTAGE

- **NO POTS: Internal component header configures amplifier for applications**
- **Conservative design for high MTBF**
- **Low cost solution for small brushless motors to 1/3 HP**

PRODUCT DESCRIPTION

Model 503 is a complete pwm servoamplifier for applications using DC brushless motors in torque (current) mode. It provides six-step commutation of three-phase DC brushless motors using 60° or 120° Hall sensors on the motor, and provides a full complement of features for motor control. These include remote inhibit/enable, directional enable inputs for connection to limit switches, and protection for both motor and amplifier.
The /Enable input has selectable active level (+5V or gnd) to interface with most control cards.
/Pos and /Neg enable inputs use fail-safe (ground to enable) logic.
Power delivery is four-quadrant for
bi-directional acceleration and deceleration of motors.
Model 503 features 500W peak power output in a compact package using surface mount technology.
An internal header socket holds components which configure the various gain and current limit settings to customize the 503 for different loads and applications.

Separate peak and continuous current limits allow high acceleration without sacrificing protection against continuous overloads. Peak current time limit is settable to match amplifier to motor thermal limits.
Header components permit compensation over a wide range of load inductances to maximize bandwidth with different motors.
Package design places all connectors along one edge for easy connection and adjustment while minimizing footprint inside enclosures.
High quality components and conservative ratings insure long service life and high reliability in industrial installations.
A differential amplifier buffers the reference voltage input to reject common-mode noise resulting from potential differences between controller and amplifier grounds.
Output short circuits and heatplate overtemperature cause the amplifier to latch into shutdown. Grounding the reset input will enable an auto-reset from such conditions when this feature is desired.

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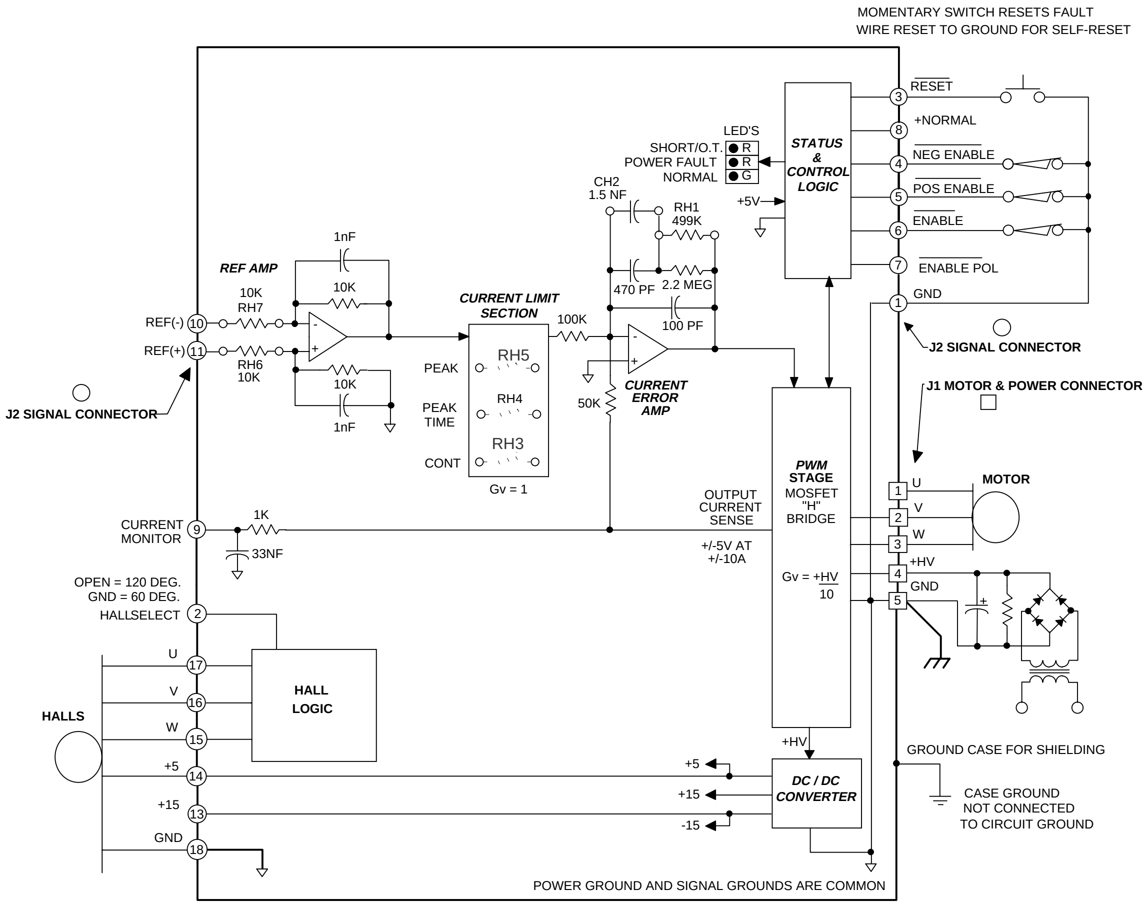
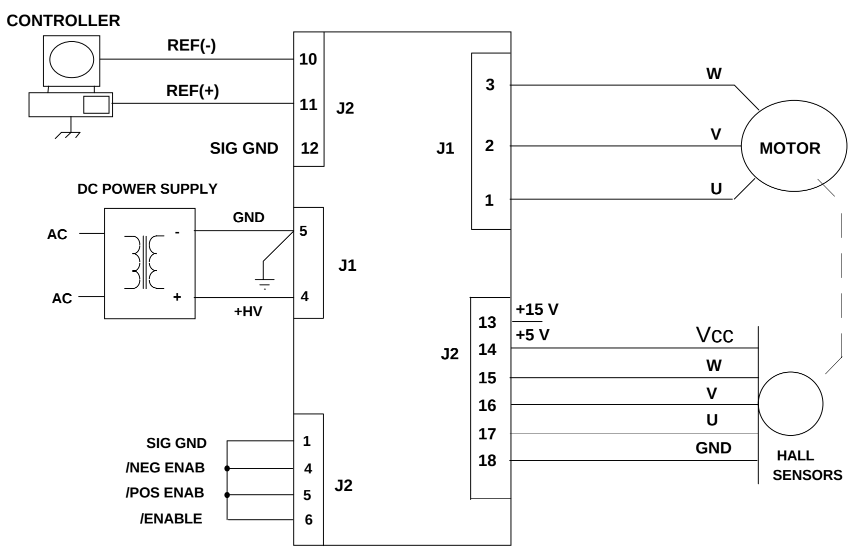
http://www.copleycontrols.com

FUNCTIONAL DIAGRAM



TYPICAL CONNECTIONS



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APPLICATION INFORMATION

To use the model 503 set up the internal header with the components that configure the transconductance, current limits, and load inductance. Current-limits and load inductance set up the amplifier for your particular motor, and the transconductance defines the amplifiers overall response in amps/volt that is required by your system.

COMPONENT HEADER SETTINGS

Use the tables provided to select values for your load and system. We recommend that you use these values as starting points, adjusting them later based on tests of the amplifier in your application.

LOAD INDUCTANCE (RH1,CH2)

Maximizes the bandwidth with your motor and supply voltage. First replace CH2 with a jumper (short). Adjust the value of RH1 using a step of 1A or less so as not to experience large signal slew-rate limiting. Select RH1 for the best transient response (lowest risetime with minimal overshoot). Once RH1 has been set. choose the smallest value of CH2 that does not cause additional overshoot or degradation of the step response.

TRANSCONDUCTANCE (RH6,7)

The transconductance of the 503 is the ratio of output current to input voltage. It is equal to 10kΩ/RH6 (Amps/Volt). RH6,and RH7 should be the same value and should be 1% tolerance metal film type for good common-mode noise rejection.

CURRENT LIMITS (RH3, 4, & 5)

The amplifier operates at the 5A continuous, 10A peak limits as delivered. To reduce the limit settings, choose values from the tables as starting points, and test with your motor to determine final values. Limit action can be seen on current monitor when output current no longer changes in response to input signals. Separate control over peak, continuous, and peak time limits provides protection for motors, while permitting higher currents for acceleration.

SETUP BASICS

1. Set RH1 and CH2 for motor load inductance (see following section).
2. Set RH3, 4, & 5 if current limits below standard values is required.
3. Ground the /Enable (/Enable Pol open), /Pos Enable, and /Neg Enable inputs to signal ground.
4. Connect the motor Hall sensors to J2 based on the manufacturers suggested signal names. Note that different manufacturers may use
   A-B-C, R-S-T, or U-V-W to name their Halls. Use the required Hall supply voltage (+5 or +15V). *Note that there is a 30 mA limit at +5V. Encoders that put-out Hall signals typically consume 200-300 mA, so if these are used, then they must be powered from an external power supply.*
5. Connect J1-4,5 to a transformer-isolated source of DC power,
   +18-55V. Ground the amplifier and power supply with an additional wire from J1-5 to a central ground point.
6. With the motor windings disconnected, apply power and slowly rotate the motor shaft. Observe the Normal (green) led. If the lamp blinks while turning then the 60/120° setting is incorrect. If J2-2 is open, then ground it and repeat the test. In order to insure proper operation, the correct Hall phasing of 60° or 120° must be made.
6. Turn off the amplifier and connect the motor leads to J1-1,2,3 in U-V-W order. Power up the unit. Apply a sinusoidal reference signal of about 1 Hz. and 1Vrms between
   Ref(+) and Ref(-), J2-10,11.
7. Observe the operation of the motor as the current monitor signal passes through zero. When phasing is correct the speed will be smooth at zero crossing and at low speeds. If it is not, then power-down and re-connect the motor.

There are six possible ways to connect the motor windings, and only one of these will result in proper motor operation. The six combinations are listed in the table below. Incorrect phasing will result in erratic operation, and the motor may not rotate. When the correct combination is found, record your settings.

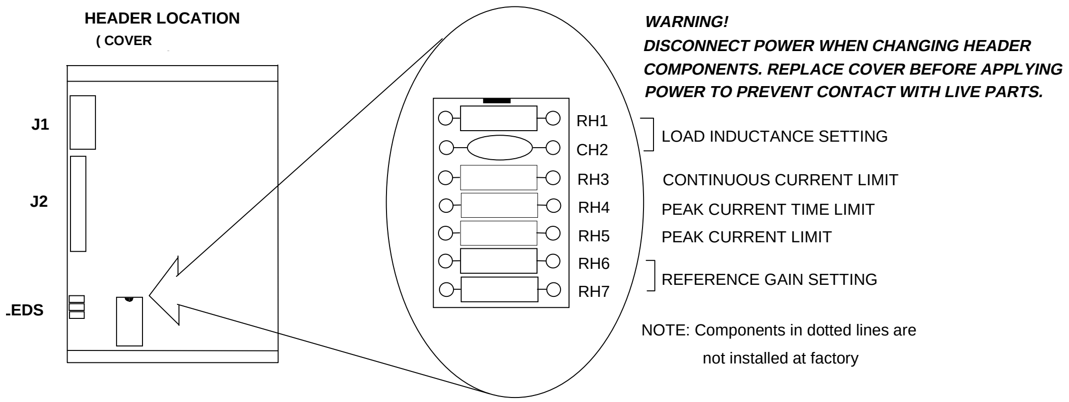
	J1-1	J1-2	J1-3
#1	U	V	W
#2	V	W	U
#3	W	U	V
#4	U	W	V
#5	W	V	U
#6	V	U	W

GROUNDING & POWER SUPPLIES

Power ground and signal ground are common (internally connected) in this amplifier. These grounds are isolated from the amplifier case which can then be grounded for best shielding while not affecting the power circuits.
Currents flowing in the power supply connections will create noise that can appear on the amplifier grounds.
This noise will be rejected by the differential amplifier at the reference input, but will appear at the digital inputs. While these are filtered, the lowest noise system will result when the power-supply capacitor is left floating, and each amplifier is grounded at its power ground terminal (J1-5). In multiple amplifier configurations, always use separate cables to each amplifier, twisting these together for lowest noise emission. Twisting motor leads will also reduce radiated noise from pwm outputs. If amplifiers are more than 1m. from power supply capacitor, use a small (500-1000µF.) capacitor across power inputs for local bypassing.

APPLICATION INFORMATION (CONT'D)

COMPONENT HEADER



CONTINUOUS CURRENT LIMIT (RH3)

Icont (A)	RH3 (Ω)
5	***open ****
4	20k
3	8.2k
2	3.9k
1	1.5k

INPUT TO OUTPUT GAIN SETTING (RH6, RH7)

Note 1

Example: Standard value of RH6 is 10kΩ, thus G = 1 A/V

PEAK CURRENT LIMIT (RH5) Note 3

Ipeak (A)	RH5 (Ω)
10	***open ****
8	12k
6	4.7k
4	2k
2	750

LOAD INDUCTANCE SETTING (RH1 & CH2) Note 2

Load (mH)	RH1	CH2
0.2	49.9 k	1.5 nF
1	150 k	1.5 nF
3	***499 k***	***1.5 nF ****
10	499 k	3.3 nF
33	499 k	6.8 nF
40	499 k	10 nF

PEAK CURRENT TIME-LIMIT (RH4) Note 4

Tpeak (s)	RH4 (Ω)
0.5	***open ****
0.4	10 M
0.2	3.3 M
0.1	1 M

Times shown are for 10A step from 0A

Notes: **** Standard values installed at factory are shown in italics.***

1. RH6 & RH7 should be 1% resistors of same value.
2. Bandwidth and values of RH1, CH2 are affected by supply voltage and load inductance. Final selection should be based on customer tests using actual motor at nominal supply voltage.
3. Peak current setting should always be greater than continuous current setting.
4. Peak times will double when current changes polarity. Peak times decrease as continuous current increases.

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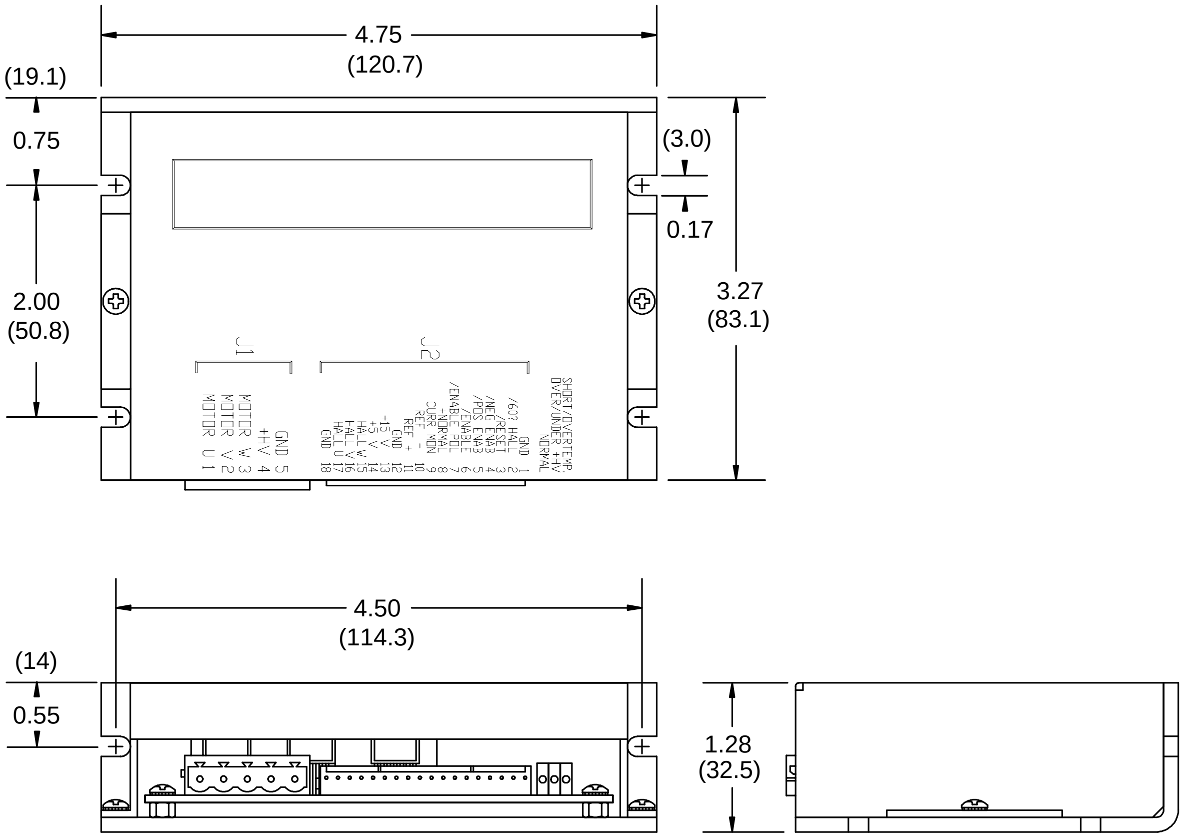
TECHNICAL SPECIFICATIONS

Typical specifications @ 25°C ambient, +HV = +55VDC. Load = 200µH. in series with 1 ohm unless otherwise specified.

OUTPUT POWER		
	Peak power	
	Unidirectional	±10A @ 50V for 0.5 second, 500W
	After direction change	±10A @ 50V for 1 second, 500W
	Continuous power	±5A @ 50V, 250W
OUTPUT VOLTAGE		Vout = 0.97HV -(0.4)(Iout)
MAXIMUM CONTINUOUS OUTPUT CURRENT		
	Convection cooled, no conductive cooling	±2A @ 35°C ambient
	Mounted on narrow edge, on steel plate, fan-cooled 400 ft/min	±5A @ 55°C
LOAD INDUCTANCE		
	Selectable with components on header socket	200 µH to 40mH (Nominal, for higher inductances consult factory)
BANDWIDTH		
	Small signal	-3dB @ 2.5kHz with 200µH load
	Note: actual bandwidth will depend on supply voltage, load inductance, and header component selection	
PWM SWITCHING FREQUENCY		
		25kHz
ANALOG INPUT CHARACTERISTICS		
	Reference	Differential, 20K between inputs with standard header values
GAINS		
	Input differential amplifier	X1 as delivered. Adjustable via header components RH6, RH7
	PWM transconductance stage	1 A/V (output vs. input to current limit stage)
OFFSET		
	Output offset current (0 V at inputs)	20 mA max. (0.2% of full-scale)
	Input offset voltage	20 mV max (for 0 output current, RH6,7 = 10kΩ)
LOGIC INPUTS		
	Logic threshold voltage	HI: ≥ 2.5V , LO: ≤1.0V, ***+5V Max on all logic inputs***
	/Enable	LO enables amplifier (/Enable Pol open) , HI inhibits; 50 ms turn-on delay
	/POS enable, /NEG enable	LO enables positive and negative output currents, HI inhibits
	/Reset	LO resets latching fault condition, ground for self-reset every 50 ms.
	/Enable Pol (Enable Polarity)	LO reverses logic of /Enable input only (HI enables unit, LO inhibits)
LOGIC OUTPUTS		
	+Normal	HI when unit operating normally, LO if overtemp, output short, disabled, or power supply (+HV) out of tolerance HI output voltage = 2.4V min at -3.2 mA max., LO output voltage = 0.5V max at 2 mA max. ***Note: Do not connect +Normal output to devices that operate > +5V***
INDICATORS (LED's)		
	Normal (green)	ON = Amplifier enabled, no shorts or overtemp, power within limits
	Power fault (red)	ON = Power fault: +HV <18V OR +HV > 55V
	Short/Overtemp (red)	ON = Output short-circuit or over-temperature condition
CURRENT MONITOR OUTPUT		±5V @ ±10A (2A/volt), 10kΩ, 3.3nF R-C filter
DC POWER OUTPUTS		
	+5VDC	30mA (Includes power for Hall sensors)
	+15VDC	10mA
		Total power from all outputs not to exceed 200mW.
PROTECTION		
	Output short circuit (output to output, output to ground)	Latches unit OFF (self-reset if /RESET input grounded)
	Overtemperature	Shutdown at 70°C on heatplate (Latches unit OFF)
	Power supply voltage too low (Undervoltage)	Shutdown at +HV < 18VDC (operation resumes when power >18VDC)
	Power supply voltage too high (Overvoltage)	Shutdown at +HV > 55VDC (operation resumes when power <55VDC)
POWER REQUIREMENTS		
	DC power (+HV)	+18-55 VDC @ 10A peak.
	Minimum power consumption	2.5 W
	Power dissipation at 5A output, 55VDC supply	10W
	Power dissipation at 10A output, 55VDC supply	40W
THERMAL REQUIREMENTS		
	Storage temperature range	-30 to +85°C
	Operating temperature range	0 to 70°C baseplate temperature
MECHANICAL		
	Size	3.27 x 4.75 x 1.28 in. (83 x 121 x 33mm)
	Weight	0.52 lb (0.24 kg.)
CONNECTORS		
	Power & motor	Weidmuller: BL-125946; Phoenix: MSTB 2.5/5-ST-5.08
	Signal & Halls	Molex: 22-01-3167 housing with 08-50-0114 pins

OUTLINE DIMENSIONS

Dimensions in inches (mm.)



ORDERING GUIDE

Model 503	5A Continuous, 10A Peak, +18-55VDC Brushless Servoamplifier

OTHER BRUSHLESS AMPLIFIERS

Model 505 Same power output as 503. Adds Hall / Encoder tachometer feature for velocity loop operation.

5001 Series Six models covering +24-225VDC operation, 5-15A continuous, 10-30A peak. With optional Hall / Encoder tachometer, and brushless tachometer features.

Model 513R Resolver interface for trapezoidal-drivemotors. Outputs A/B quadrature encoder signals and analog tachometer signal for velocity loop operation. +24-180VDC operation, 13A continuous, 26A peak.

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Fax: (781) 329-4055
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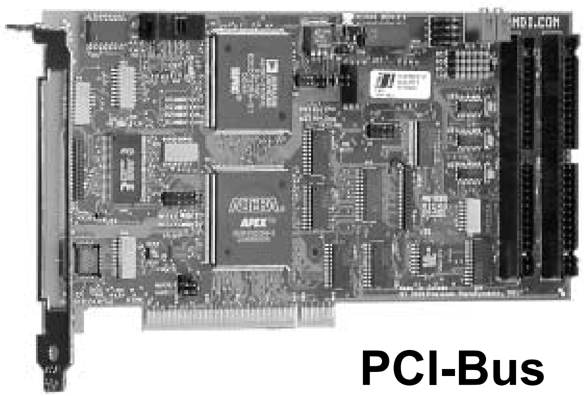
http://www.copleycontrols.com

Data Sheet for the MC4000 DSP Motion Control Card



PCI-Bus

MC4000

The Versatile Motion Control Board with Easy-to-Use Software

The **MC4000** is Precision MicroDynamics' multi-axis, PCI-Bus motion control DSP board. It is ideal for both Original Equipment Manufacturers (OEMs) and Test and Measurement applications.

PC-BASED MULTI-AXIS DSP MOTION CONTROL

Four off-the-shelf versions of the MC4000 are offered: the **MC4000-PRO**, four servos and four steppers; the **MC4000-LITE**, four servos; the **MC4000-STEP**, four closed-loop steppers and four open-loop steppers; and the **MC4000-DUAL**, four dual-encoder servos.

MC4000 Version	Servos	Open-loop Steppers	Closed-loop Steppers	Analog Inputs	Position Cap./Com.
PRO	**4**	**4**	**-**	**4**	**4**
LITE	**4**	**-**	**-**	**-**	**-**
STEP	**-**	**4**	**4**	**-**	**-**
DUAL	**4***	**-**	**-**	**4**	**4**

***Dual Encoder Axes**

The MC4000 uses a 32-bit floating-point DSP that performs path planning, feedback regulation and other real-time computations, freeing the host PC for process application and graphical user interface (GUI) software.

The MC4000 is supported by powerful development software: **MotionSuite™** and **MotionSuite-PRO™**. MotionSuite includes: **MCI-SoftLIB™**, easy-to-use, thread-safe C-library of motion control functions; and **MotionTools™**, easy-to-use GUI for machine tuning and set up.

MotionSuite-PRO provides DSP programming capability for the MC8000. MotionSuite-PRO includes: **LIBeRTy™** real-time multi-tasking software; **CMC-SoftLIB™**, a C-library of motion control routines; **SHARC-Trig™**, a mathematics C-library; and **MotionTools**.

Application areas for the MC4000 include: semiconductor processing, material handling and test, CNC machine tool control, automotive test and measurement, aerospace, medical equipment, industrial materials processing, and food packaging and processing.

Custom modifications to standard DSP executables and FPGA firmware are performed for qualified OEMs.

PRECISION MICRO DYNAMICS

07/2001

Precision MicroDynamics, Inc., #3 - 512 Frances Ave., Victoria, B.C., Canada, V8Z 1A1, Tel. 250-382-7249, Fax. 250-382-1830, Web. Http://www.pmdi.com

Hardware

MC4000-PRO Overview

The **MC4000-PRO** is a DSP-based motion control board that communicates with the Host PC through the PCI bus. The card supports data rates with the host PC as high as 7.2 MBytes/s . The core of the MC4000-PRO is its 32-bit floating-point DSP processor. The standard memory configuration is 48 bits wide and includes 20K words of on-chip SRAM, 256K words of on-board SRAM and 330Kwords of FLASH memory.

The **MC4000-PRO's** 2 external connectors are arranged into **four groups,** with each group having 30 physical contacts.

I/O Type		Number	Details
Encoders		4	- A, B, Z, A*, B* and Z*
Analog	In	4	- ADC differential line
	Out	8	- DAC
Digital	In	24	- user programmable
	Out	8	- user programmable
	High-speed I/O	16	- Stepper outputs, auxiliary encoders and registration

Digital Signal Processor

The DSP is Analog Devices' 32-bit **ADSP-21061** SHARC processor running at 40MHz with 20K words of on-chip memory. Other SHARC DSP processors available include:

DSP Type	On-board SRAM	Other details
ADSP-21060	80K words	Linkports
ADSP-21062	40K words	Linkports

Nonvolatile Memory

Permanent memory storage for stand-alone operations is provided. The board comes with 330K words of FLASH memory for storage of machine parameters and programs.

Quadrature Encoders

The quadrature encoder inputs support single-ended and differential encoder signals. +5V and 12V are available for encoder power. The standard encoder input frequency is 10 MHz edge rate after 4X decoding (20 & 40MHz options are available).

Analog

Each group has a 14-bit (65,536 Levels) differential analog input and two 16-bit (16,384 Levels) outputs. These signals sample at a rate of 88kHz. Each **group** has the following:

Analog	Quantity	Name	Resolution	Range
Inputs	1	ADC	14 bits	± 10V
Outputs	2	DAC A and B	16 bits	± 10V

Digital

Each group has 6 inputs, 2 outputs and 4 high-speed lines for a total of 48 Digital I/O lines. Unreserved lines can be programmed to meet OEM requirements. Each **group** has the following:

Digital I/O*	Quantity	Typical Use
Inputs	6	HOME, LIM-, LIM+
Outputs	2	AmpEnable
High-speed	4	Stepper Motor- Pulse or Dir, Position Capture or Compare, and Auxiliary A and B.

*TTL compatible (sink and source 10 mA)

SYNC and WDOG

The SYNC signal can be passed between multiple **MC4000-PRO** boards for synchronization of motion control or data acquisition. If the WDOG times out, the user can program any number of discrete events to take place (ex. emergency stop).

Linkport

A ten-pin connector contains the WDOG and SYNC signals, along with the Linkport connections, enabling communication between two separate **MC4000-PRO** DSPs directly (transfer rates up to 160Mbits/sec). This is an advanced feature available with the ADSP-21060 or ADSP-21062 options.

Software

Two development software suites are available for the MC4000. These are (i) MotionSuite and (ii) MotionSuite-PRO.

MotionSuite

Register Access is offered for Microsoft Windows operating systems. This library provides functions for reading and writing the board's registers.

MotionTools is a GUI application program used to set up, and tune motion control for the MC4000. Evaluate MotionTools for free over the Internet. After downloading MotionTools you will be able to control servomotors directly over the Internet. To learn more visit http://www.pmdi.com.

MCI-SoftLIB high-level motion control C-library contains a set of functions that accesses the services of PMDi's DSP-based motion control cards.

Initialization File is a text-based file that sets motion control parameters for use by the MCI-SoftLIB library.

MotionSuite-PRO

MotionSuite-PRO provides all of the features and components of MotionSuite, but adds the capability of programming at the DSP level. It is distributed with the additional software components: CMC-SoftLIB, LIBeRTy and SHARC-Trig.

CMC-SoftLIB is a comprehensive software library of C-language routines for motion control application development.

LIBeRTy is PMDi's real-time, multi-tasking kernel for use with Analog Devices' SHARC DSP Processors.

SHARC-Trig is an optimized trigonometry C-library.

Specifications

Computer Compatibility

- PCI Bus, 4.25in. high by 8.25in. long

Digital Signal Processor and Memory

- Analog Devices' ADSP-2106X SHARC DSP
- 128K words of 48-Bit on-board SRAM
- 330K words of 48-Bit on-board FLASH memory

SYNC

- Synchronizes DAC output, ADC and encoder input
- SYNC generated by on-board timer or software

Programmable Interval Timer

- 0.25 s to 512 seconds with 0.12 s resolution
- Can generate SYNC signal and/or PC interrupts

Watchdog Timer

- 3.85 s to 125ms
- Forces DAC outputs to 0 Volts on timeout and digital output to low for emergency shutdown

Quadrature Encoder Input Channels

- 24-bit up-down counters. A,B,Z inputs, invertible for phasing and universal index pulse, digitally filtered

- Preload in hardware by index pulse or by software register
- Each encoder axis input configurable for differential or single ended termination
- Power for +5V and +12V encoders
- Up to 40MHz maximum input edge rate

D/A Channels (16-bit)

- Maximum output rate 88kHz
- Accuracy ±1 LSB
- Voltage output range ±10V

A/D Channels (14-bit)

- Maximum sampling rate 88kHz
- Accuracy ±1 LSB
- Voltage input range ±10V

Digital Inputs

- Digital inputs typically used for machine limits and home
- TTL Level, 10mA sink

Digital Outputs

- Digital outputs, usually used as amp enable and emergency shutdown.
- TTL Level, 10mA source

Stepper Motor Outputs

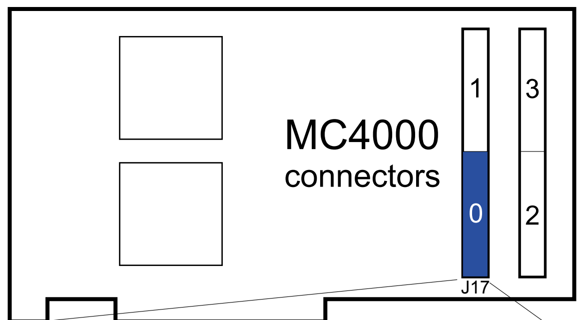
- Pulse and direction bits
- 2MHz max (1 Hz resolution)

High-Speed Digital I/O

- Stepper motor outputs (step and direction)
- Position capture inputs or compare outputs
- Auxiliary encoder inputs (A and B)
- Unreserved high speed I/O for OEMs
- Additional functions for qualified OEM customers
  - PWM Outputs
  - Temposonics™ Inputs
  - Handwheel Inputs

Pin-outs

Four off-the-shelf versions of the MC4000 are available. These are the **MC4000-PRO**, **MC4000-LITE**, **MC4000-STEP** and **MC4000-DUAL**. Each version has four standard 60-pin IDC connectors. Each connector is logically separated into two 30-pin groups, with each group supporting one motion axis (except for the PRO and STEP versions that have two axes per group for a total of 8 axes).



Group0		MC4000-PRO	MC4000-LITE	MC4000-STEP	MC4000-DUAL
PIN	FUNCTION	DESCRIPTION	DESCRIPTION	DESCRIPTION	DESCRIPTION
1	+5V	+5V Power for Encoders	+5V Power for Encoders	+5V Power for Encoders	+5V Power for Encoders
2	GND	Encoder GND	Encoder GND	Encoder GND	Encoder GND
3	A	Encoder Channel A	Encoder Channel A	Encoder Channel A	Encoder Channel A
4	A*	Encoder Channel A Complement	Encoder Channel A Complement	Encoder Channel A Complement	Encoder Channel A Complement
5	B	Encoder Channel B	Encoder Channel B	Encoder Channel B	Encoder Channel B
6	B*	Encoder Channel B Complement	Encoder Channel B Complement	Encoder Channel B Complement	Encoder Channel B Complement
7	Z	Encoder Index Pulse	Encoder Index Pulse	Encoder Index Pulse	Encoder Index Pulse
8	Z*	Encoder Index Pulse Complement	Encoder Index Pulse Complement	Encoder Index Pulse Complement	Encoder Index Pulse Complement
9	+12V	+12V Power for Encoders	+12V Power for Encoders	+12V Power for Encoders	+12V Power for Encoders
10	GND	Digital Ground	Digital Ground	Digital Ground	Digital Ground
11	DIN0	HOME1	HOME1	HOME1	HOME1
12	DIN1	LIM1+	LIM1+	LIM1+	LIM1+
13	DIN2	LIM1-	LIM1-	LIM1-	LIM1-
14	DIN3	HOME2	DIN3	HOME2	DIN3
15	DIN4	LIM2+	DIN4	LIM2+	DIN4
16	DIN5	LIM2-	DIN5	LIM2-	DIN5
17	GND	Digital Ground	Digital Ground	Digital Ground	Digital Ground
18	+5V	+5V from PC	+5V from PC	+5V from PC	+5V from PC
19	DOUT0	Amp Enable 1	Amp Enable 1	Amp Enable 1	Amp Enable 1
20	DOUT1	Amp Enable 2	DOUT1	Amp Enable 2	DOUT1
21	GND	Digital Ground	Digital Ground	Digital Ground	Digital Ground
22	HSD0	Stepper Motor- Pulse 1	NC	Stepper Motor- Pulse 1	Aux. Encoder Channel A
23	HSD1	Stepper Motor- Direction 1	NC	Stepper Motor- Direction 1	Aux. Encoder Channel B
24	HSD2	Position Compare Output	NC	Stepper Motor- Pulse 2	Position Compare Output
25	HSD3	Position Capture Input	NC	Stepper Motor- Direction 2	Position Capture Input
26	AGND	Analog Ground	Analog Ground	NC	Analog Ground
27	DAC B	Analog Output B	NC	NC	Analog Output B
28	DAC A	Analog Output A	Analog Output A	NC	Analog Output A
29	AD+	Analog Input +ve Diferential Line	NC	NC	Analog Input +ve Diferential Line
30	AD-	Analog Input +ve Diferential Line	NC	NC	Analog Input +ve Diferential Line

*** Pin-outs shown for Group0 only (Connector J17 pin 1-30). Functions for Group1 to Group3 are the same.**

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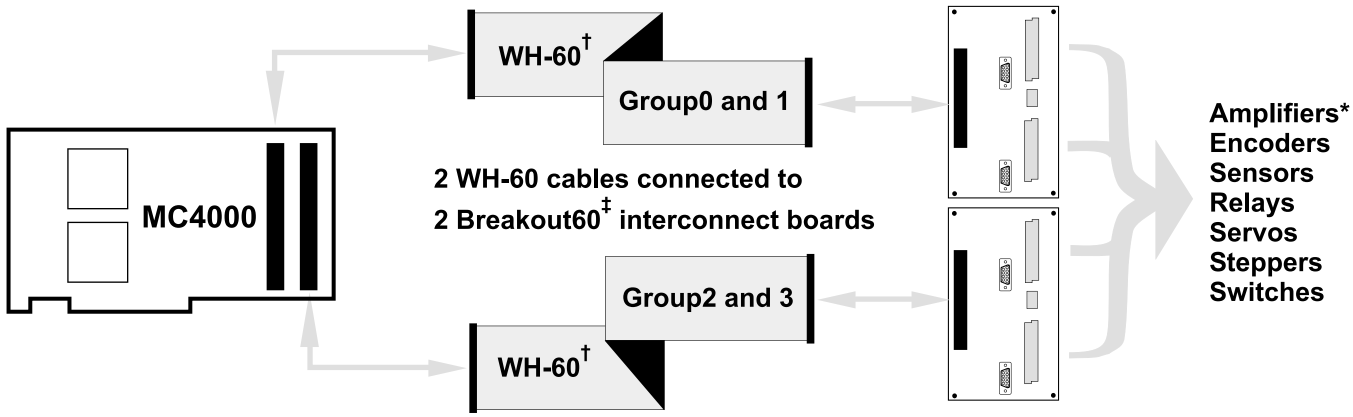
System Configuration



† also available in shielded version (WHS-60)
‡ regular terminal block available (TERM/60)
* PMDi Linear amplifier available (BTA-XXV-6A)

Ordering Information

MC8000-PRO*	4 servo axes and 4 stepper axes motion control and data acquisition board
-LITE*	4 servo axes motion control board
-STEP*	4 closed-loop stepper axes and 4 open-loop stepper axes motion control board
-DUAL*	4 servo axes dual-encoder motion control and data acquisition board
WH-60	60 pin ribbon cable assembly (for two axes)
WHS-60	60 pin shielded cable assembly (for two axes)
BreakOut60	Breakout board with opto-isolation (for two axes)
TERM/60	60 contact screw-terminal break-out board (for two axes)
SYNC/10-ZZ	10 pin SYNC connector cable, ZZ the number of connectors = number of boards synchronized
DNG-9	Encoder line fault detection circuitry for open-circuit, short-circuit, and voltage level
MotionSuite	MotionTools, MCI-SoftLIB, and Register Access libraries
MotionSuite-PRO	MotionSuite plus LIBeRTy, SHARC-Trig, and CMC-SoftLIB

* Register Access libraries included.

Note: MC8000 boards using Linkports require non-standard DSP chips. Call Precision MicroDynamics for information.

Warranty: The MC8000 is warranted according to the Terms and Conditions of the Sale and is effective for ONE YEAR after shipment.

Representative's Information

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